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REVIEW

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Current knowledge, status, and future for plant and fungal diversity in Great Britain and the UK Overseas Territories

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Societal Impact Statement

We rely on plants and fungi for most aspects of our lives. Yet plants and fungi are under threat, and we risk losing species before we know their identity, roles, and potential uses. Knowing names, distributions, and threats are first steps toward effective conservation action. Accessible products like field guides and online resources engage society, harnessing collective support for conservation. Here, we review current knowledge of the plants and fungi of the UK and UK Overseas Territories, highlighting gaps to help direct future research efforts toward conserving these vital elements of biodiversity.

Summary

This review summarizes current knowledge of the status and threats to the plants and fungi of Great Britain and the UK Overseas Territories (UKOTs). Although the body of knowledge is considerable, the distribution of information varies substantially, and we highlight knowledge gaps. The UK vascular flora is the most well studied and we have a relatively clear picture of its 9,001 native and alien taxa. We have seedbanked 72% of the native and archaeophyte angiosperm taxa and 78% of threatened taxa. Knowledge of the UKOTs flora varies across territories and we report a UKOTs flora comprising 4,093 native and alien taxa. We have conserved 27% of the native flora and 51% of the threatened vascular plants in Kew's Millennium Seed Bank, UK. We need a better understanding of the conservation status of plants in the wild, and progress toward completion or updating national red lists varies. Site-based protection of key plant assemblages is outlined, and progress in identifying Important Plant Areas analyzed. Knowledge of the non-vascular flora, especially seaweeds remains patchy, particularly in many UKOTs. The biggest gaps overall are in fungi, particularly non-lichenized fungi. Considerable investment is needed to fill these knowledge gaps and instigate effective conservation strategies.

KEYWORDS

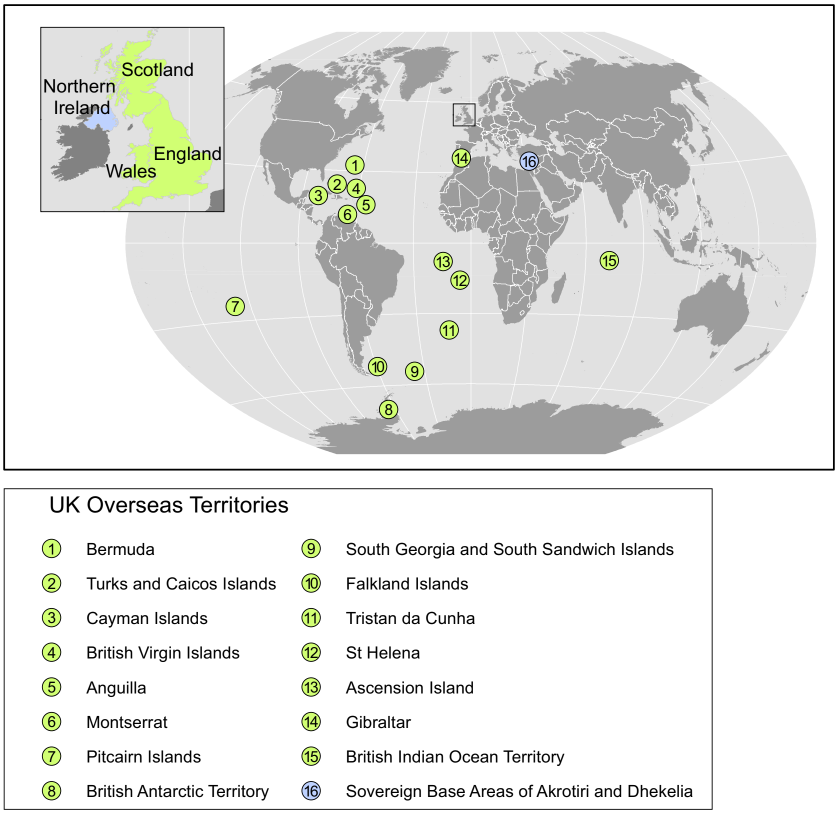
Important Fungal Areas (IFAs), Important Plant areas (IPAs), red listing, seed banking, Tropical Important Plant Areas (TIPAs), UK, UK Overseas Territories (UKOTs)

1 | INTRODUCTION

In this article, we summarize current knowledge of the status and threats to the plants and fungi of Great Britain and the UK Overseas Territories (UKOTs; former British colonies that have elected to remain under British sovereignty). The UK Government reaffirmed its close relationship with UKOTs in its 2012 White Paper setting out its commitment to work with the UKOTs to address the challenges we face, with a strong focus on the environment and biodiversity (UK Government, 2012). The 25-year Environment Plan (UK Government, 2018) contains renewed commitments to improve the environment of the UK and UKOTs at species and site levels. The UK's ratification of biodiversity-related Multilateral Environmental Agreements has been extended to many UKOTs (CBD, 2020; CITES, 2020; Ramsar, 2020).

UKOTs are remarkably diverse, consisting of islands and peninsulas spread across the world's oceans (Figure 1). Together they have a surface area approximately seven times that of mainland UK and are collectively home to many endemic species (McPherson, 2016), with some estimates putting this at 94% of known endemic British species (Churchyard et al., 2014). In contrast, the UK endemic flora is composed of relatively large numbers of apomictic taxa in a small number of genera; most of the sexual species also occur elsewhere in Europe. In addition, due to many species being at the edge of their range in the UK, they are often more abundant elsewhere in their range (Wigginton, 1999). The bryophyte flora similarly shows low levels of endemism, but includes a higher proportion of rare, widely disjunct species for which the UK has globally significant populations.

The UK and the UKOTs together host a globally unique flora and mycota constituting an important component of the world's plant and fungal diversity. Our review highlights the knowledge gaps relating to the biodiversity of some of the remotest islands and archipelagos in contrast to the often-detailed knowledge, particularly of the flora, of Britain. In the face of global change, for conservation to be effective,



* Northern Ireland and the Sovereign Base Areas of Akrotiri and Dhekelia were excluded from this review.

FIGURE 1 Map showing location of the UK and the UK Overseas Territories

we have a responsibility to know and understand the biota of these geographically scattered parts of the world. The gaps identified here are often the same as those for other remote and understudied parts of the world, and lessons learned with rare oceanic island endemics will inform conservation elsewhere. Global biodiversity faces unprecedented threats with 75% of terrestrial and 66% of marine environments already severely altered by human activities (UN, 2020), we need transformational change to stop biodiversity loss. To conserve and sustainably use biodiversity, we need to know what it is and what state it is in. We hope this review will promote a new renaissance in plant and fungal exploration and as we plug the information gaps for the UK and particularly for UKOTs this will lead to a greater realization of the importance of retaining our remaining biodiversity and foster a greater recognition of the importance of these far-flung parts of the world.

1.1 | Geographical coverage

We follow the established coverage for the British Red Data Book for vascular plants in only reviewing Great Britain due to the difficulty in biogeographical terms of treating Britain and Northern Ireland as a unit, or Britain and Ireland together. The Channel Islands (Bailiwick of Jersey and Bailiwick of Guernsey) are excluded on biogeographical grounds, due to the greater affinity of their plants and fungi with the nearby continental mainland of Europe (Wigginton, 1999).

We treat St Helena, Ascension, and Tristan da Cunha separately because of their individually unique biodiversity. We exclude the Sovereign Base Areas of Akrotiri and Dhekelia due to the difficulty of disaggregating data from the island of Cyprus.

1.2 | Taxonomic coverage

For plants, we review available information for vascular plants, bryophytes (hornworts, liverworts, and mosses), and freshwater, terrestrial, and marine algae. For fungi, we review Basidiomycota, Ascomycota (including lichenized fungi), and other groups for which data are available.

2 | HISTORICAL OVERVIEW

The flora of mainland UK is one of the most studied worldwide and is well represented in herbaria. With c. 620,000 specimens, the British and Irish Herbarium at the Natural History Museum, UK (BM; herbarium acronyms follow Index Herbariorum, NYBG, 2020), holds material of 100% of native genera and >99% of native species, often collected throughout their British and Irish range (Natural History Museum, 2020). The Sloane Herbarium of c. 80,000 specimens, perhaps the largest pre-Linnean collection, provides a significant repository of first British records. The herbarium at the Royal Botanic Gardens, Kew, UK (K), includes an estimated >185,000 UK plant collections. Among the c. 3,000,000 specimens held in the Herbarium at the Royal Botanic Garden

Edinburgh, UK (E) are c. 350,000 specimens of Scottish plants collected since the 18th century (Royal Botanic Garden Edinburgh, 2020). The National Museum Wales, UK herbarium (NMW) houses 550,000 specimens, including comprehensive UK collections, and the herbarium at The National Botanic Garden of Wales, UK, holds c. 28,000 UK specimens of vascular plants and macroalgae. Cambridge University Herbarium, UK (CGE), houses c. 300,000–400,000 UK specimens (of c. 1,100,000); this collection was used in Sell and Murrell (1996, 2006, 2009, 2014, 2018). These collections are of great importance for studies of historical distributions and changes in the face of climate change.

Major publications have focused on the origin of the UK flora and its history since prehistoric times (e.g., Godwin, 1956; Proctor, 2013), and distributions documented in detail (e.g., Preston, Pearman, & Dines, 2002; Stace, 1997

, 2019). Some studies highlighted changes in the vascular plant flora due to anthropogenic and other pressures (e.g., Braithwaite, Ellis, & Preston, 2006; Preston et al., 2002).

The bryophyte flora is well studied and documented, with major herbarium collections at BM, E, CGE, and NMW, the last housing BBSUK (the British Bryological Society herbarium), the voucher repository for all new vice-comital records. Four comprehensive hectad-level distribution atlases have been produced (Blockeel, Bosanquet, Hill, & Preston, 2014; Hill, Preston, & Smith, 1991, 1992, 1994).

The seaweed flora of the UK is also one of the most studied; BM holds material of virtually every species recorded from the UK, with collections being used for studies of rare and non-native species (e.g., Brodie, John, Tittley, Holmes, & Williamson, 2007; Brodie, Wilbraham, & Pottas, 2013; Brodie, Wilbraham, Pottas, & Guiry, 2016). There is an atlas of red, green, and brown seaweeds for Britain and Ireland (Hardy & Guiry, 2003, 2006) and a provisional red data list (Brodie et al., 2013).

In contrast to the British flora, UKOTs floras are relatively unstudied, and accounts covering all territories concentrate on wildlife rather than the flora specifically (e.g., Churchyard et al., 2014; Hayhow et al., 2019; McPherson, 2016; Oldfield, 1987). Some territories are floristically well studied with St Helena having most comprehensive historical records (Burchell, 1805–1810; Cronk, 1989, 2000; Lambdon, 2012; Lambdon & Cronk, 2020; Melliss, 1875). Only the Cayman Islands has a modern flora (Proctor, 2012); others, e.g., for Bermuda (Britton, 1918) and Falkland Islands (Moore, 1968, 1973) need revision. Regional floristic treatments cover individual territories, e.g., Howard (1974) for Montserrat and Anguilla, Correll and Correll (1982) for Turks & Caicos Islands, and Acevedo-Rodríguez and Strong (2012) for Caribbean UKOTs. Comprehensive guides to native and introduced vascular plants exist for Bermuda (Pettit, 2016), Gibraltar (Linares, Harper, & Cortes, 1996), Falkland Islands (Heller, Upson, & Lewis, 2019), South Georgia (Galbraith, 2011; Upson, Myer, Floyd, Lee, & Clubbe, 2017), and St Helena (Lambdon, 2012). Other treatments cover limited elements of the flora, e.g., Anguilla (Walker, Hodge, Homer, & Johnson, 2005), Ascension (Ashmole & Ashmole, 2000; Fairhurst, 2004), British Virgin Islands (BVI TIPAs National Team, 2019), Montserrat (Holliday, 2009), St Helena (Cronk, 2000), Turks and Caicos Islands (Wood, 2003), and Tristan da Cunha (Ryan, 2007; Tyler & Rothwell, 2006). Some territories have developed online resources (Linares et al., 2020, for Gibraltar; QEIIBP, 2020, for the Cayman Islands). Seaweed data for the UKOTs are patchy, although c. 5,000 herbarium specimens are held at BM. Bermuda's marine algae have been studied extensively for over a century (Collins & Hervey, 1917; Schneider, 2003; Taylor & Bernatowicz, 1969).

Few territories have established herbaria (NYBG, 2020). The National Herbarium of the Falkland Islands (FINH) contains c. 1,500 specimens, mostly native/introduced vascular plants, mosses, and lichens and a small algal collection (FINH, 2020). The Bermuda Natural History Museum Herbarium contains over 800 terrestrial plants, 500 marine algae, and new Fungarium with over 50 specimens (Smith, pers. com.). The Antarctic Plant Database holds information on specimens held in the British Antarctic Survey herbarium (AAS). There are >70,000 records, predominantly mosses and lichens, but also vascular plants, non-lichenized fungi, and algae collected mainly in Antarctic and sub-Antarctic regions (British Antarctic Survey, 2020; Peat, 1998). Collections from South Georgia and the South Sandwich Islands started in 1775 and Antarctica in 1834.

In response to these gaps and lack of access to herbarium records, Kew's UKOTs team developed the UKOTs Online Herbarium, an open access web-based portal containing digitized records of Kew and UKOTs herbarium specimens, DNA bank and seed collections, and field observations. It comprises 31,692 botanical records and 22,631 images (UKOTs, 2020). Digitized specimen images have been repatriated to territories, particularly important where local bandwidth and computer facilities make internet access unreliable.

2.1 | British fungi

The largest national reference collections of dried British non-lichenized fungi are housed at K and E. Most British lichen specimens are at BM and E, but K and NMW have large collections.

Kew's Fungarium was established in 1875 (Buczacki, 2001) and now holds c. 1.25 million specimens (including c. 375,000 from the UK; Royal Botanic Gardens, Kew, 2020a), the largest in the world. The UK is the main source country for the c. 500,000 specimens (40%) that have been databased (Willis, Paton, & Smith, 2018). The Edinburgh Fungarium holds c. 116,000 British specimens (R. Yahr, pers. comm.).

Well-documented recording began after the inauguration of the British Mycological Society (BMS) in 1896. The Society regularly organized field meetings yielding published lists of species recorded. These were later digitized and developed into national recording databases, now managed by the British Lichen Society, the BMS, and the Fungus Conservation Trust. However, these databases, for non-lichenized taxa at least, depend on the recording of the often ephemeral and unpredictable emergence of reproductive structures rather than the detection of fungal mycelia. Although Spooner and Roberts (2005) stated that the "British Isles rank amongst the world's most thoroughly recorded areas for fungi", it is also true that even our native mycota remains inadequately documented.

2.2 | UKOTs fungi

The mycota of the UKOTs remains largely unknown, and few territories have full checklists or species guides. Some regional lists exist (e.g., Minter, Rodríguez-Hernández, & Mena-Portales, 2001), but data on specific territories are difficult to access for the non-specialist. Waterston (1947) listed over 700 fungi in Bermuda. Aptroot (2012) produced a guide to the lichens of St Helena, and Riddle (1918) reported 85 species and varieties of lichens for Bermuda, including 10 endemics [revised by Sterrer (1998) to 92 species/10 endemics].

Study of the pine forests of the Turks and Caicos Islands identified 18 ectomycorrhizal taxa, mainly associated with *Pinus* and *Coccoloba* (Dani Sanchez et al., 2016). Preliminary documentation of Basidiomycota of St Helena (Ryvarden & Larsson, 2015; Spirin, Ryvarden, & Miettinen, 2015) was based on 1 week of collecting (217 specimens). Similar work, albeit restricted to heterobasidiomycetes, in the British Virgin Islands was reported by Roberts (2008). Recent metabarcoding fungal community studies of soils around endemic trees on St Helena (Detheridge et al., 2020) revealed low numbers of Basidiomycota and high numbers of Capnodiales (Ascomycota), an order usually associated with leaf surfaces. Kohlmeyer and Kohlmeyer (1977) published a key to filamentous higher marine fungi in Bermuda.

3 | TOTAL NUMBER OF SPECIES

3.1 | British plants

The Botanical Society of Britain and Ireland (BSBI) database lists 9,001 taxa of vascular plants (including species, subspecies, and varieties, but not hybrids, cultivars, or forma), of which 3,025 (34%) are considered native. For information about hybrids, see Box 1. The numbers and percentages at different taxonomic levels are summarized in Table 1. At the level of genus, 524 genera are recorded to have native members and 959 genera are recorded to have non-native members in Britain. Of the native taxa in Britain, 141 are defined

Box 1 Hybridization in vascular plants

Natural hybridization has been intensively studied in the British flora, with Stace (1975) and Stace, Preston, and Pearman (2015) representing landmark publications documenting natural hybrids, their parentage, distribution, cytology, and ecological attributes. This unrivalled resource has been used to assess the frequency of hybrids and the factors that affect their persistence in nature. Although most of the 909 natural hybrids are spontaneous, 152 hybrids have become established following introductions (Preston & Pearman, 2015). Hybrids are particularly common in a few genera, with over half of the native hybrids being found in *Epilobium*, *Euphrasia*, *Rosa*, *Rumex*, and *Salix*.

The extensive knowledge base of hybridization in the British flora has led to it being used as a baseline comparison for the prevalence of hybridization in animals (Mallet, 2005), one of eight floras used in a global meta-analysis of plant hybridization (Mitchell et al., 2019), and a model for studying hybridization under global change (Vallejo-Marín & Hiscock, 2016). In addition, focused research on hybrids has been instrumental in understanding the evolutionary processes that shape the outcome of hybridization. Hybrids between self-fertilizing *Geum urbanum* and outcrossing *G. rivale* (Jordan et al., 2018), native *Hyacinthoides non-scripta*, and introduced *H. hispanica* (Kohn, Ruhsam, Hulme, Barrett, & Hollingsworth, 2019) have been extensively studied, and current studies are focused on, among others, the homoploid hybrid ragwort *Senecio squalidus* (James & Abbott, 2005), the recent allopolyploid *Mimulus peregrinus* (Vallejo-Marín, Buggs, Cooley, & Puzey, 2015), and the widespread invasive allopolyploid *Spartina anglica* (Ainouche & Gray, 2016). Key findings are that hybridization is most common in disturbed/degraded habitats and that introduced alien taxa can play a key role in hybridization. Hybridization can also result in the formation of novel lineages that contribute to the diversity of endemics, e.g., in *Sorbus s.l.* (Hamston et al., 2018; Pellicer, Clermont, Houston, Rich, & Fay, 2012; Rich, Houston, Robertson, & Proctor, 2010).

Natural hybrids have been recorded from several UKOTs, but there is no systematic review of their status. Three natural hybrids are known from the British Virgin Islands: *Tillandsia* x*lineatispica*, *Anthurium* ×*selloanum*, and *Coccoloba krugii* × *C. uvifera* (BVI TIPAs National Team, 2019). Several hybrids are known from St Helena, including *Trochetiopsis* ×*benjaminii* (Cronk, 2000) and *Commidendrum* hybrids (Gray et al., 2017); hybridization in *Elaphoglossum* has resulted in a new endemic species (Eastwood, Vogel, Gibby, & Cronk, 2004) and, in contrast, the Critically Endangered *Wahlenbergia linifolia* is at risk of genetic erosion due to hybridization with the more common and vigorous *W. angustifolia* (Lambdon & Ellick, 2016c; Yang, Lambdon, Williams, & Cronk, 2017). *Gaultheria antarctica* × *G. plumula* is a natural hybrid reported from the Falkland Islands (Heller et al., 2019). Hybridization of native endemics with non-native taxa (often introduced for horticulture) is an increasing problem. In Bermuda, there is concern over the hybridization of the endemic *Juniperus bermudiana* with *J. virginiana* (Adams, 2008; Adams & Wingate, 2008). In the Cayman Islands, hybridization with an introduced relative is considered a threat to the genetic distinctiveness of the endemic *Cordia sebestina* var. *caymanensis* (Burton, 2008).

TABLE 1 Taxa of vascular plants in Britain listed on the BSBI database, organized by taxonomic level and by native versus non-native status

	Total natives	Total non-natives (alien)	Total natives + non-natives	Percentage native	Percentage non-native
Species	2,233	5,406	7,639	29	71
Subspecies	425	280	705	60	40
Variety	367	290	657	56	44
Total	3,025	5,976	9,001	34	66

as aliens in Ireland. Conversely, 15 taxa are native in Ireland but considered alien in Britain. For information about non-native plants in Britain, see Box 2.
There are differences between this and other lists, largely due to the inclusion (or not) of apomictic taxa [see, e.g., Stace (2019) vs. Sell and Murrell (1996, 2006, 2009, 2014, 2018)]. Table 2 documents endemic vascular plant taxa by country aimed at directing conservation priorities and includes 792 endemic taxa (649 for Britain), most of which are apomicts [*Alchemilla* (2), *Dryopteris* (1), *Hieracium* (332), *Limonium* (12), *Ranunculus auricomus* group (58), *Rubus* (183), *Sorbus* (38), and *Taraxacum* (53)], but there are 25 sexual species and 26 sexual subspecies (Rich, unpubl. data).

The checklist of the bryophyte flora of Britain and Ireland (Hill, Blackstock, Long, & Rothero, 2008) was updated by Blockeel et al. (2014), who listed 1,069 species (767 mosses, 298 liverworts, and four hornworts), five subspecies (three liverworts, two mosses), and 33 varieties (three liverworts, 30 mosses). Sixteen native species (previously overlooked, natural range extensions or taxonomic re-assessments) and one new introduction have since been added (cf. 112 species added in 1975–2000; Smith, 2001). Of seven bryophyte species currently considered to be endemic, three are of questionable status and two are probably present elsewhere in Europe. Several taxa previously regarded as endemic have been found to occur elsewhere, often as wide disjunctions, or shown to be forms of other species.

The latest revision of the seaweed checklist [Rhodophyta, Chlorophyta, and Ochrophyta (Phaeophyceae)] for Britain (Brodie et al., 2016) includes 644 taxa (348, 110, and 186 taxa, respectively). Thirty-one non-native species (5%) were listed, but the numbers may be higher and will include naturalized species that are thought indigenous.

Freshwater algal diversity is less well documented. John, Whitton, and Brooks (2011) listed 2,480 species (3,173 taxa; 14 phyla). The most species-rich group is Chlorophyta (1,588 species and 626 subspecific taxa). Much of the diversity of Chlorophyta can be attributed to the desmids, of which c. 1,400 taxa have been recorded for Britain. Chlorophyta also include stoneworts (currently 30 species, but in need of revision). Diatoms, not included by John et al. (2011), number c. 2,800 species in freshwater environments in Britain (Jüttner et al., 2020).

3.2 | UKOTs plants

There has been no systematic analysis of the status of the UKOTs flora, and data are not yet centralized to enable this analysis to be completed. Data presented here are the first attempt at a synthetic analysis based on specimen records available in online databases. We used specimen data from Plants of the World Online (POWO, 2020) supplemented by selected checklists, resolving synonymy issues as far as possible to produce a summary of vascular plants from each territory (Table 3). We estimate that the current known vascular flora of the UKOTs comprises 4,093 taxa (includes species, subspecies, and varieties). The status (native or introduced) of c. 3% of the flora is still uncertain. On average, 60% of the flora is native (cf. 34% for Britain), ranging from 88% for Turks and Caicos Islands to 21% for St Helena and 18% for Ascension, the territories most impacted by invasive species. For information about introduced plants in the UKOTs, see Box 3. However, there has been much less focus on non-native plants in many territories, and some figures may reflect few dedicated surveys. Our analysis reveals 191 endemics, of which 17 are extinct. The last documented extinction in 2004 was *Nesiota elliptica*, a monotypic genus on St Helena (Lambdon & Ellick, 2016a) and *Lachanodes arborea* became Extinct in the Wild as recently as 2012 (Lambdon & Ellick, 2016b).

Botanical exploration continues adding to our knowledge, including publishing new species, e.g., *Eragrostis episcopulus*, first recorded in St Helena in 2012 (Lambdon, Darlow, Clubbe, & Cope, 2012), and *Nassauvia falklandica* in the Falkland Islands (Upson, Clubbe, & Hind, 2013). Species range extensions are regularly recorded, e.g., in the British Virgin Islands (Bárrios, Sustache, Goyder, & Hamilton, 2020; BVI TIPAs National Team, 2019). Endemic plants thought extinct have been found again, e.g., *Anogramma ascensionis* (Ascension; Baker et al., 2014; Gray et al., 2005), *Abutilon pitcairnense* (Pitcairn; Smyth et al., 2010), and *Mellissia begoniifolia* (St Helena; Fay, Thomas, & Knapp, 2007).

We know much less about non-vascular plants in UKOTs. For St Helena, there are records for c. 110 species. Twenty-six species are endemic, and the island is considered a centre of endemism for bryophytes (Wigginton, 2012). For Ascension, 87 species (60 mosses, 23 liverworts, and four hornworts) have been recorded, following extensive fieldwork (Pressel, Matcham, Supple, & Duckett, 2017). Of these, 12 are endemic and four are near endemics. There is an online liverworts and hornworts portal for the Falkland Islands providing accounts of 146 taxa (Crabtree, Tangney, Larrain, & von Konrat, 2020), but data are patchy for other territories, e.g., for Bermuda, Britton (1918), reported 51 native mosses (two endemic) and liverworts, and Sterrer (1998) reported 25 species of liverworts (no endemics).

Box 2 Established aliens in Britain

As a result of intensive management of much of the British landscape for agriculture, forestry, and horticulture, non-native plant species have become a significant part of the vascular plant flora. Stace and Crawley (2015) reported that, at 57%, the proportion of alien plants in the UK is probably the highest in Europe. Increasing numbers of alien species are becoming established, and the BSBI publishes regular updates on "adventives and aliens" (e.g., Berry, 2020) and their latest figures indicate that 66% of the species in Britain are non-native (Table 1).

There are alien taxa in other terrestrial groups. A few bryophyte species (*c*. 15) are thought to be introductions through horticulture. Two early imports, *Orthodontium lineare* (first record 1920) and particularly *Campylopus introflexus* (1941), have achieved extensive British ranges significantly impacting native flora. *Lophocolea semiteres* and *L. bispinosa* are proving invasive, but their impact is difficult to assess. In the marine environment Brodie et al. (2016) listed 31 seaweed species considered non-native to Great Britain. One of these, Japanese wireweed (*Sargassum muticum*), is now widespread following its arrival in the 1970s; where it is spreading on the Scottish coast it is considered to present a significant threat to marine biodiversity (Gaywood, Boon, Thompson, & Strachan, 2016).

Not all non-native species represent a threat to native flora. Many archaeophytes are treated as important from a cultural or conservation point of view, e.g., snake's-head fritillary (*Fritillaria meleagris*) and Tenby daffodil (*Narcissus obvallaris*), or are familiar "wild plants", e.g., shepherd's purse (*Capsella bursa-pastoris*) and the sycamore (*Acer pseudoplatanus*). A few non-natives represent a major threat to native habitats such as *Rhododendron ponticum* (CABI, 2019a) and *Impatiens glandulifera* (CABI, 2019b). They can also have impacts on the economy (e.g., *Reynoutria japonica* (CABI, 2019c) and human health, e.g., *Ambrosia artemisiifolia* (CABI, 2019d). Aquatic weeds (e.g., *Crassula helmsii*, *Ludwigia grandiflora*, and *Myriophyllum aquaticum*) that spread by small fragments through water courses represent a serious problem, and these were the first to be banned from sale in the UK in 2014 (National Archives, 2020).

The main pathway for the introduction of non-native plants is for the movement of plants in trade and horticulture (Dehnen-Schmutz & Touza, 2008). This constitutes the most important pathway in terms of numbers, although it is less significant in terms of impact (Non-Native Species Secretariat, 2019). Efforts need to be focused on the prevention of future threats by identifying those species that present a significant risk of becoming invasive. Roy et al. (2014) assessed 591 species not yet established in the UK and identified four plant species that presented a high risk if they escaped. The successful establishment of non-native species may to some extent be attributed to poor land management and habitat degradation.

The impact of climate change on alien plants is being investigated. There is some evidence that ornamental species that were previously not a threat in the UK now have the potential to spread into the wider environment. For example, the tree of heaven (*Ailanthus altissima*) is beginning to spread in the urban heat island of London. Some also may have the potential to provide resilience to climate change, e.g., holm oak (*Quercus ilex*) and cherry laurel (*Prunus lusitanica*), as well as providing ecosystem services for native invertebrates (Salisbury et al., 2017, 2020).

TABLE 2 Number of endemic vascular plant taxa in Britain, Ireland, Channel Islands, and Isle of Man (Rich, unpubl. data)

Geographical region	Number of endemics
Channel Islands	3
England	284
Isle of Man	0
Scotland	185
Wales	58
Britain	122
Northern Ireland	0
Republic of Ireland	14
Ireland	7
Britain & Ireland	119
Total	792

Information on seaweeds is similarly sparse. Recent fieldwork on the Falkland Islands and associated molecular studies have resulted in a checklist of 253 species (Brodie et al., unpublished) including 57 new records (a 22% increase in known diversity). A total of 125 species are recorded from Tristan da Cunha, although further taxonomic work will undoubtedly reveal more (Saunders, Huisman, Vergés, Kraft, & Le Gall, 2017). Saunders, Brooks, and Scott (2019) compared data to the comprehensive marine floristic work (Baardseth, 1941), who noted that endemism for marine macroalgae was relatively high (40%). Chamberlain (1965) reported 40 marine algal for Gough Island. South Georgia has a unique and diverse seaweed flora with 127 species (Wells, Brewin, & Brickle, 2011). Price and John (1980) recorded 52 species for Ascension, increased to 82 by Tsiamis et al. (2017).

3.3 | British fungi

Estimates of the numbers of UK species range from 12,000 to 20,000 species to, more recently, 18,000 to 20,000 species (e.g., Dines & McCarthy, 2014; NBN, 2020). However, there is still no comprehensive annotated checklist of British mycota. Significant milestones include checklists for British agarics and boleti (Dennis,

TABLE 3 Numbers and status of vascular plants in the UKOTs. Data from Plants of the World Online (POWO, 2020)

Territory	Native taxa	Introduced taxa	Taxa of uncertain origin	Extinct taxa	Endemic taxa	Total accepted taxa
Anguilla	329	197	45	0	2	571
Ascension Island	41	187	0	5	7	228
Bermuda	220	384	1	3	10	605
British Antarctic Territory	3	1	0	0	0	4
British Indian Ocean Territory	59	198	0	0	0	257
British Virgin Islands	874	283	126	0	4	1,283
Cayman Islands	606	223	1	0	29	830
Falkland Islands	181	180	0	0	14	375
Gibraltar	550	64	26	0	1	640
Montserrat	761	225	97	1	3	1,083
Pitcairn Islands	106	44	1	1	19	151
Saint Helena	102	395	0	9	44	497
South Georgia	26	60	0	0	0	86
South Sandwich Islands	3	0	0	0	0	3
Tristan da Cunha	106	154	0	0	49	260
Turks and Caicos Islands	436	61	1	0	9	498
Total all UKOTs	[a]	[a]	[a]	17	191	4,093

[a]Column totals excluded as they overestimate because of species overlap between neighboring territories, particularly in the Caribbean, included in individual territory totals.

Orton, & Hora, 1960), Ascomycotina (Cannon, Hawksworth, & Sherwood-Pike, 1985), lichens (Coppins, 2002), British & Irish Basidiomycota (Legon & Henrici, 2005), and Welsh rusts, smuts, and powdery mildews (Chater & Woods, 2019; Woods, Chater, Smith, Stringer, & Evans, 2018; Woods, Stringer, Evans, & Chater, 2015). Over 16,500 names of Basidiomycota were considered by Legon and Henrici (2005) for their checklist of 3,670 taxa (species or lower ranks). Since then there have been, on average, c. 27 net additions per year (Ainsworth & Henrici, 2020). Longer lists for individual sites usually reflect greater recording effort and specialist input (Spooner & Roberts, 2005).

The ascomycete checklist includes c. 11,100 species (including lichens) and 62,500 names (including synonyms) but needs curation and updating. The lichen list includes 1960 accepted names and 502 lichenicolous fungi. The number of ascomycetes added to the list each year is probably higher than for basidiomycetes. Over the past 10 years, 230 new lichens/lichenicolous fungi have been added to the list.

Defining and listing alien fungi is problematic due to the lack of evidence regarding their mode of arrival and their propensity for natural airborne dispersal. Difficulties were reviewed for Basidiomycota by Legon and Henrici (2005), who adopted a stringent definition. Fungi alien to Europe were listed in Desprez-Loustau (2009) and Essl and Lambdon (2009). Plant pathogens present a major challenge, e.g., ash dieback arrived in the UK via natural spread from the continent and on imported plant material, but it is native to East Asia. For information about the UK response to ash dieback, see Box 4. Recent new finds are likely to have arrived via range extension due to climate change (especially in southern England), but it is often not possible to demonstrate that they were previously absent.

Thirty-seven species of lichens/lichenicolous fungi were considered as endemic/probable endemic by Woods and Coppins (2012), 14 of which have since been found elsewhere. Assessing endemism for lichens is complicated by the fact that the sterile/sorediate morph and the fertile morph of a species can be visually distinct (e.g., Ertz, Coppins, & Sanderson, 2018).

Of the 39 Basidiomycota with British holotypes described between 2000 and 2019, evidence was found for all but eight also occurring overseas. At this stage these should not be regarded as endemics because some are inconspicuous and only known from the type locality and most are still poorly known, even in Britain. Spooner and Roberts (2005) noted the existence of >300 (mostly inconspicuous microfungal) species described from Britain with no known records elsewhere, but concluded that these data highlight our poor understanding of fungal distributions; few endemic fungi are likely to occur in Britain.

3.4 | UKOTs fungi

There are huge gaps in our knowledge of UKOTs fungi. As few studies have been conducted and online databases are lacking, we are unable to provide a summary of the UKOTs mycota. On St Helena, lichens dominate much of the barren lowlands, extending into the upland cloud forest; Aptroot (2012) reported 225 species

Box 3 Established aliens in the UKOTs

Invasive Alien Species are an increasing threat to the plants of the UKOTs and rank as the second most common threat to species listed on the IUCN Red List (IUCN, 2020). Although there has been no systematic analysis of the non-native flora across the UKOTs since Varnham (2006), many territories report an increasing number of alien plants in their floras and rank invasive species as one of the top three threats to biodiversity (e.g., Clubbe, Hamilton, & Corcoran, 2010; Gray, Pelembe, & Stroud, 2005; GSGSSI, 2016; Hughes et al., 2020; Kingston & Waldren, 2003, 2005; Lambdon, 2012; Rojas-Sandoval & Acevedo-Rodríguez, 2015). Although there is uncertainty in these data, Table 3 indicates that the territories with particularly high non-native components are Ascension (82%), St Helena (79%), British Indian Ocean Territory (77%), South Georgia (70%), Tristan da Cunha (68%), and Bermuda (63%). Recent work coordinated through the GB Non-Native Species Secretariat has identified increased biosecurity as a key solution and a horizon scanning exercise has prioritized actions and identified likely next species threats (GBNSS, 2020).

Research and control of invasive species is underway in many territories. In South Georgia, a Non-Native Plant Management Strategy is being implemented controlling 41 non-native species (GSGSSI, 2016). In the Falkland Islands, 14 high-risk invasive plants have been identified for control (Lewis, 2014) with *Berberis microphylla* (calafate) of particularly concern and the focus of current control activities. In Bermuda, a significant proportion of the landscape is covered in invasive vegetation which presents the biggest threat to the survival of the indigenous flora (Government of Bermuda, 2020), and Wolsak, Wingate, and Cronk (2018) surveyed levels of invasives in Bermudian terrestrial vegetation. *Casuarina equisetifolia* is reducing native plant species richness in the Turks and Caicos Islands (TCI) and models predict that it poses a threat to at least three of the TCI endemic plants (Hardman, Williams, Manco, & Hamilton, 2012). On Pitcairn Island, native species are being out competed by non-native *Syzygium jambos* (Smyth, Waldren, & Kingston, 2010). Because of its aggressive growth and the decline in its wood being harvested for fuel, it has formed dense canopies across the island and is preventing native species regeneration (Smyth, 2008), including the endemic *Abutilon pitcairnense* (Smyth et al., 2010). A study in Montserrat used prediction mapping of the spread of *Psidium guajava* and *Cryptostegia madagascariensis* which showed a near complete overlap with the habitat requirements of the endemic *Rondeletia buxifolia* and if left unchecked could result in its extirpation (Jones, Clubbe, & Hamilton, 2012; Stow, 2008). Eighteen invasive species that threaten native biodiversity have been identified in BVI (BVI TIPAs National Team, 2019). Invasive species have had a huge impact on St Helena's plant diversity where endemic plants have been eliminated from 96.5% of the island (Lambdon & Cronk, 2020). In the Peaks National Park, a suite of invasive species threatens the unique flora of the remaining cloud forest, with *Austroeupatorium inulifolium* (whiteweed) of particular concern (Lambdon, 2012). *Pseudoscleropodium purum*, an introduced moss, has spread rampantly on St Helena and is outcompeting native bryophytes (Wigginton, 2012).

(99 genera) of lichens for the island (nine endemics). Sterrer (1998) listed 92 lichens (ten endemic) and 627 non-lichenized fungi (40 endemic) for Bermuda and Berger and LaGreca (2014) added 105 new lichen species records. Recent collecting work in Bermuda has listed 38 Ascomycota and 84 Basidiomycota for a forthcoming field guide (Smith, pers. comm.). Fryday, Ornage, Ahti, Øvstedal, and Crabtree (2019) published a checklist of 408 lichens for the Falkland Islands (150 new records for the archipelago), and Orange (2016) produced a field guide to the 100 most common lichens.

4 | GLOBALLY SIGNIFICANT PLANTS. FUNGI AND HABITATS OF THE UK AND UKOTs

In the face of global (largely anthropogenic) change, actions to mitigate the effects of the environmental challenges we face are widely recognized to be urgently needed if we are to avoid major losses to biodiversity and destruction/degradation of habitats. However, it is also generally perceived that conserving representative populations of all species is not achievable, and decisions need to be made about priorities for action.

One approach to this process of “triage” (e.g., Hayward & Castley, 2018, and references therein) is to assess the significance of the biota of countries, regions, or habitats against those of other parts of the world, and the significance can be assessed in various ways, depending on the aims and desired outcomes. In a broad sense, these can be divided into those that focus on (a) species richness; (b) phylogenetic distinctiveness; (c) presence of unique or rare genetic variation within species/populations; and (d) the regional or global significance of the ecosystems/habitats.

Species richness is a relatively easy measure and it has led, for example, to the recognition of global biodiversity hotspots (sensu Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). However, this approach generally fails to include an assessment of the evolutionary distinctiveness of the species (treating all species as equal), the presence of unique or rare genetic variation, or the rarity of the habitat types that are formed by the species. In recent decades, assessment of phylogenetic distinctiveness of taxa has been increasingly used to overcome the first of these issues, and phylogenetic diversity (PD) sensu Faith (1992) links diversity and

Box 4 Managing the threats to *Fraxinus excelsior* in the UK

Fraxinus excelsior (European ash) is a large tree, native to the UK and found across much of mainland Europe. In Britain, ash is the second most abundant tree species in small woodland patches and the third most abundant in larger areas of forest. Also found in hedgerows, by roads and railways and in urban environments (Thomas, 2016), it is estimated that there are 125 million ash trees in woodlands and 27–60 million ash trees outside woodlands in the UK (Department for Environment, Food & Rural Affairs, 2015; Forestry Commission, 2013, 2018).

Ash is highly valued for its wood and supports biodiversity and ecological function. Almost 1,000 species are associated with ash, of which 45 are believed to have only ever been found on ash (Mitchell et al., 2014a, 2014b). The social and environmental value of ash woodlands in Great Britain have been estimated at >£230 million per year (Department for Environment, Food & Rural Affairs, 2019). However, ash is under considerable pressure from ash dieback caused by the fungus *Hymenoscyphus fraxineus* originally from Asia, but now recorded throughout Europe (EPPO, 2018a; Spence, Hill, & Morris, 2020). A recent analysis of data across Europe found mortality rates up to 85%, depending on woodland type (Coker et al., 2019). The total cost of ash dieback to the UK has been estimated at £14.6 billion based on the cost of dealing with the impacts of the disease (e.g., felling), replanting, and loss of ecosystem services (Hill et al., 2019).

Ash is also under threat from the emerald ash borer (EAB; *Agrilus planipennis*), a pest from eastern Asia (EPPO, 2018b). Despite efforts to contain the pest, it has killed tens of millions of ash trees and resulted in loss of ecosystem services, resulting in hundreds of millions of dollars of economic losses in North America (EPPO, 2013; Kovacs et al., 2010; McKenney et al., 2012). First confirmed in Europe in Moscow in 2005, it continues to move westwards (EPPO Reporting Service, 2007).

In 2014–2019, UK Government spent >£6 million on research on ash. One outcome of this has been a screening trial for tolerant trees which has resulted in the planting of 3,000 trees in an archive, as the basis for a future breeding programme. In 2019, the Department for Environment, Food and Rural Affairs, UK (Defra), published its *Ash Research Strategy*, consolidating existing knowledge about key pest and disease threats to ash and their management and identifying future research needs (Department of Food Environment & Rural Affairs, 2019). Eleven research themes grouped under three key outcomes were identified, following the framework laid out in the Tree Health Resilience Strategy (Department for Environment, Food & Rural Affairs, 2018).

distinctiveness on the basis of phylogenetic trees, and modifications such as EDGE (Evolutionarily Distinct/Globally Endangered; e.g., Isaac, Redding, Meredith, & Safi, 2012) include level of threat as part of the assessment. However, how PD methods should be applied is still debated (Véron, Saito, Padilla-García, Forest, & Bertheau, 2019, and references therein).

In the case of Britain and the UKOTs, vascular plant species richness is low (although levels of endemism for some UKOTs are high, e.g., in the isolated oceanic islands such as St Helena and Tristan da Cunha; cf. Table 2 vs. Table 3). PD is also likely to be low, but this remains to be rigorously tested, although the British vascular flora has been used as a test case for a variant of the EDGE approach (Pearse et al., 2015) and St Helena's fragile flora containing unique monotypic genera has recently been reviewed (Lambdon & Cronk, 2020).

Many species in the British flora have been studied genetically and the dominant pattern seen is that the genetics of British populations is a subset of that found elsewhere in the range, but relatively few detailed studies exist for species from the UKOTs (see Box 5 for more detail). Much less information is available for other plant groups and fungi.

At an ecosystem/habitat level a wide range of prioritization methods have been employed to highlight global importance with Key Biodiversity Areas (KBAs) being the most recent, identifying sites contributing significantly to the global persistence of biodiversity (IUCN, 2016). Important Plant and Important Fungal Areas (IPAs and IFAs) are the global system to identify the most important sites for wild plant and fungal species (Anderson, 2002; Hutchinson & Dines, 2008). Sites qualify under one or more of three criteria, Criterion A (species of international importance), Criterion B (assemblages of species of international importance), and Criterion C (threatened habitats; Plantlife, 2019, 2020) and 79 IPAs are based on threatened habitats (34 in England, 27 in Scotland, and 18 in Wales). Table 4 summarizes IPAs and IFAs in Britain.

Revised SSSI (Sites of Special Scientific Interest) Guidelines for British lichens and associated microfungi and for non-lichenized fungi have been published (Bosanquet, Ainsworth, Cooch, Genney, & Wilkins, 2018; Sanderson, Wilkins, Bosanquet, & Genney, 2018). These incorporate new criteria to assess sites for direct protection of fungal diversity and include lists of fungal assemblages. Some British sites are of international significance, e.g., those with outstanding assemblages of hyper-oceanic lichens, nitrogen-sensitive grassland fungi, and fungi inhabiting dead beech (*Fagus sylvatica*).

Two UKOTs have completed IPA assessments. Upson (2012) identified 17 IPAs across the Falkland Islands. These are now listed as key sites of biodiversity interest (FIG, 2016a), providing a guide for implementing the Biodiversity Framework (FIG, 2016b). Following the revised IPA concept for tropical regions (Darbyshire et al., 2017), 18 Tropical IPAs (TIPAs) have been identified in the British Virgin Islands which support concentrations of globally and nationally threatened plants and nationally threatened habitats (BVI TIPAs National Team, 2019). Preliminary work to identify TIPAs has been undertaken in Turks and Caicos Islands (Hardman et al., 2012) and Montserrat (Jones, 2008).

Other site-based prioritizations have been conducted in most territories to declare protected areas and reserves. For example,

Box 5 Genetic diversity in UK and UKOTs vascular plants and bryophytes

UK plants

DNA barcoding data exist for all UK native seed plants. Initial work produced a complete DNA barcode dataset for the flora of Wales (de Vere et al., 2012), which has since been expanded to all of Britain, with a full three-locus DNA barcode of *rbcL*, *matK*, and ITS2 available for multiple individuals from 1,016 taxa; data for at least one locus are available for c. 1,500 taxa (de Vere et al., unpublished). These data provide a resource for plant identification and studies of ecological processes and interactions. For bryophytes, the liverwort flora has been DNA barcoded for *rbcL*, *matK*, *psbA-trnH*, and ITS2 (RBGE, unpublished), resulting in the detection of several new species (e.g., Bell et al., 2012); further potential new species await a follow-up study (Forrest et al., unpublished).

There are many studies looking at patterns of genetic diversity in British species, and >1,000 taxa have some genetic study, on British or non-British populations (Ruhsam et al., 2018). The British flora has been profoundly impacted by past glaciations, resulting in large-scale changes in distributions and many native species have undergone dramatic and recent changes in range in response to climate change (Wang et al., 2014). This recent history has limited the opportunity for unique highly divergent genetic lineages to evolve. There are some cases of divergent lineages being restricted to the UK, but the dominant signal is that species present in the UK have a subset of the genetic variation found elsewhere, as seen in, e.g., *Calluna vulgaris* (Rendell & Ennos, 2002), *Cypripedium calceolus* (Fay et al., 2009), and *Silene nutans* (Martin, Touzet, Van Rossum, Delalande, & Arnaud, 2016). Next-generation sequencing approaches are being increasingly used to investigate diversity in British species (e.g., *Primula farinosa*; Theodoridis et al., 2017).

Despite the limited evidence for historically isolated genetic lineages, there is a well-established body of literature showing genetic adaptation to environmental conditions in Britain, and widespread species often show differential adaptations across their British range. Population differences are often driven by environmental heterogeneity, with Britain having considerable variation in rainfall, temperature, elevation, and soil type. For example, reciprocal transplant experiments in *Nardus stricta* revealed reproductive variation between Scottish populations, with clear home-site advantage related to elevation (Miller & Cummins, 2014).

UKOTs plants

By comparison, research on genetic diversity in UKOTs species is relatively sparse and restricted to investigations on species of conservation concern and under threat of extinction. Richardson et al. (Richardson, Fay, Cronk, and Chase 2003); 2001b, 2001a, studied phylogenetics and population genetics of *Nesiota* (now extinct) and *Phylica*, focusing on the species endemic to St Helena and Tristan da Cunha. Other studies include population genetics research in *Mellissia begoniifolia* (Fay et al., 2007), *Elaphoglossum* (Eastwood et al., 2004), *Commidendrum*. (Gray et al., 2017), and *Wahlenbergia* (Yang et al., 2017) from St Helena, and *Pinus caribaea* var. *bahamensis* (Sanchez, Ingrouille, Cowan, Hamilton, & Fay, 2014; Dani Sanchez et al., 2019), *Vachellia anegadensis* (Bárrios, 2015), and *Varronia rupicola* (Hamilton, 2016) from UKOTs in the Caribbean.

St Helena's unique cloud forest is protected as the Peaks National Park (St Helena Government, 2020). Ascension's Green Mountain National Park conserves remaining cloud forest (Ascension Island Government, 2020; Duffey, 1964). The British Virgin Islands' Systems Plan includes 21 terrestrial National Parks (Gardner, Smith-Abbott, & Woodfield, 2008) and Montserrat's key biodiversity is conserved in the Centre Hills Reserve (Young, 2008). Bermuda successfully re-afforested the Nonsuch Island Nature Preserve, a more than 50-year effort to establish a pre-colonial forest (Wingate, 1985).

5 | CURRENT STATUS AND THREATS TO PLANT AND FUNGAL DIVERSITY

Anthropogenic activities are significantly impacting the natural environment, with recent studies suggesting that 75% of terrestrial lands worldwide have experienced some type of land-use change (IPBES, 2019; Venter et al., 2016), and biodiversity loss is ranked as the third highest risk to the global economy (World Economic Forum, 2020). The most important drivers of biodiversity change are widely recognized as habitat loss and fragmentation, invasive alien species, pollution, exploitation, and climate change (IPBES, 2019; IPPC, 2020). The State of Nature reports show the importance of these drivers across Britain and the UKOTs (Hayhow et al., 2019; State of Nature, 2013, 2016).

5.1 | British plants

The GB Red Listing group for vascular plants maintains a Red List for Great Britain (hosted on the BSBI website) with published amendments based on International Union for Conservation of Nature (IUCN) criteria. Currently, 152 non-apomictic species are listed as Critically Endangered (CR) or Endangered (EN). There is a published Red List for Great Britain (Cheffings & Farrell, 2005)

TABLE 4 Numbers of important plant areas and important fungus areas at the European level in Britain

	Britain	England	Scotland	Wales	Notes/Reference
Vascular plants	101	58	28	15	Hutchinson and Dines (2008) (six of these are of European importance as Important Arable Plant Areas [IAPA]; Byfield & Wilson, 2005)
Stoneworts	25	13	8	4	Stewart (2004)
Bryophytes	48	22	20	6	Hutchinson and Dines (2008)
Seaweeds	8	6	1	1	Brodie et al. (2007)
Desmids	6	0	1	1	Only desmids have been assessed among freshwater algae; Brodie et al. (2007)
Lichens	52	26	17	9	Edwards (2007)
Fungi	236				Evans, Harper, and Marren (2004)

and country Red Lists for England (Stroh et al., 2014) and Wales (Dines, 2008).

The bryophyte Red List (Church, Hodgetts, Preston, & Stewart, 2001) has been revised (Hodgetts, 2011); >20% of liverworts and >25% of mosses are in an IUCN threat category (Table 5). A European Red List (Hodgetts, Cálix, & Englefield, 2019) listed six British species as CR (one RE), 16 EN, 46 Vulnerable (VU) [two Regionally Extinct (RE)], 65 Near Threatened (NT; three RE), and 12 Data Deficient (DD; one RE); thus, c. 13.5% of British bryophytes are threatened at the European level, many also at the global level. Lists of nationally rare/scarce bryophytes have also been published (Preston, 2006, 2010).

A provisional Red Data list for UK seaweeds revealed that 34% are DD, indicating that further work is needed to determine species distribution and status (Brodie & Wilbraham, 2014). Threats in Britain include habitat loss, harvesting, non-native species, and climate change (Brodie et al., 2016; Yesson, Bush, Davies, Maggs, & Brodie, 2015).

Among freshwater habitats, there are no undamaged rivers in lowland England and Wales and most ponds and streams are biologically degraded (Freshwater Habitats Trust, 2013). Distribution and ecological data are lacking for most groups of freshwater algae; e.g., Rhodophyta are largely restricted to streams and rivers and are sensitive to changes in water quality; their populations have almost certainly declined drastically, but little monitoring has been conducted. Stoneworts are among the most severely threatened plants in Britain and are the only algal group to have a published Red Data book (Stewart & Church, 1992). Of the 30 known species in Britain, 17 are nationally rare or extinct (Stewart, 2004); the number of sites with extant populations has declined by >60 percent in the last 30 years (Lambert, 2009). The most serious threat is nutrient enrichment (nitrates and phosphates) of water systems (Stewart, 2004), and detrimental management and encroachment and competition by successional vegetation are also factors (Stewart, 2004). Most recently, Stewart and Hatton-Ellis (2020) published a Red List of stoneworts in Wales, in which eight (44%) of the 18 species assessed were shown to be threatened.

Most freshwater algal species are unicellular, and the conservation of microscopic organisms poses difficulties due to taxonomic impediments and lack of ecological and distribution data. However, they play an important role in ecosystems and can be as threatened as their multicellular relatives. For example, desmids (Zygnematales, Chlorophyta) are a diverse group which dominate the algal flora of nutrient-poor, lentic waters and are particularly diverse in oligotrophic habitats such as moorland pools and shallow lakes. Britain has a great diversity of desmids; they are at risk given their sensitivity to water quality, but we lack the data necessary for assessing their status adequately.

5.2 | UKOTs plants

A global Red List for UKOTs is far from completion, and many territories are undertaking Red Listing assessments, concentrating initially on rare and endemic taxa. Currently 515 taxa have been globally assessed, representing c. 21% of the flora (Table 6). Of these, 135 taxa

TABLE 5 Red List categories for British mosses, liverworts, and hornworts (Hodgetts, 2011)

IUCN category	Mosses	Liverworts	Hornworts	All bryophytes
Regionally extinct	23	2	0	25[a]
Critically endangered	14	2	0	16
Endangered	33	7	0	40
Vulnerable	59	28	0	87
Near threatened	58	19	1	78
Data deficient	14	5	0	19

[a]Of these, 12 species were lost prior to 1930; no species are known to have been lost since 1980.

TABLE 6 Globally assessed UKOTs plant taxa (species, subspecies, and varieties) on the IUCN Red List (IUCN, 2020)

Territory	Native taxa	Total taxa assessed on IUCN Red List	% taxa assessed for IUCN Red List	Total threatened taxa
Anguilla	329	68	21	11
Ascension Island	41	21	51	7
Bermuda	220	51	23	66
British Antarctic Territory	3	0	0	0
British Indian Ocean Territory	59	16	27	1
British Virgin Islands	874	149	17	21
Cayman Islands	606	150	25	28
Falkland Islands	181	28	15	6
Gibraltar	550	40	7	1
Montserrat	761	116	15	4
Pitcairn Islands	106	31	29	13
Saint Helena	102	59	58	34
South Georgia	26	1	4	0
South Sandwich Islands	3	0	0	0
Tristan da Cunha	106	20	19	3
Turks and Caicos Islands	436	78	18	9

are in a threatened category [52 CR; 47 EN; 36 VU]. The top four threats listed for these taxa are development (tourism and recreation areas), invasive species, development (housing and urban areas), and agroindustry/farming (IUCN, 2020).

National Red Lists have been completed for the Cayman Islands (Burton, 2008) and the Falklands Islands (Broughton & McAdam, 2002; Upson, 2012) and are in progress in several other territories. At a national level, 27% of the Cayman Islands flora and 21% of the Falkland Islands floras are threatened, comparable to the global figure of 21% for vascular plants (Bachman et al., 2016). Bermuda tested a new rapid assessment tool which has the potential to accelerate assessments across the UKOTs (Bachman, Walker, Bárrios, Copeland, & Moat, 2020).

5.3 | UK fungi

Forty-five British species (of 280 species on the Global Red List) are globally threatened or near threatened (IUCN, 2020). Most (55%) are characteristic species of nutrient-poor managed grasslands (grazed or mown). This is undoubtedly a threatened fungal habitat deserving mainstream conservation attention in the UK, but, given the small numbers of fungi with global assessments, other equally important habitats are expected to emerge as more mycologists participate in the assessment process. Overall, the major threats affecting fungi in the UK are loss of habitat, climate change (especially drought/deluge), and nitrification (Plantlife, 2017).

There is one approved Red List for non-lichenized fungi in Britain (Ainsworth et al., 2013) covering 68 Boletaceae, of which 19% are threatened. Further Red List assessments of British fungi have been prepared but await approval.

A Red List for lichens/lichenicolous fungi in the UK (Woods & Coppins, 2012) included all 2,380 species. Of these, 220 are threatened and two thirds are nationally rare or scarce. The Red List also identified 196 species for which Britain has an international responsibility. New taxa for the UK described since 2012 have been assessed but not formally published. Although there has been some informal updating of the Red List, work is needed to revise and update it systematically.

UK temperate rainforests are a globally important lichen habitat. This habitat is globally scarce (<1% land surface) and in Europe c. 40% of the bioclimatic space available for temperate rainforest development is in the UK (DellaSala, 2011). Temperate rainforests host species-rich climax communities largely related to the *Lobarion* community (James, Hawksworth, & Rose, 1977) and the UK has international responsibility for the conservation of 30 of these species (Ellis, 2016; Woods & Coppins, 2012). These communities are now highly fragmented due to habitat loss through land-use intensification, and models of population recovery have shown that actively transplanting of individuals may be needed for their survival (Ellis, 2017; Ellis & Coppins, 2019).

Among more widespread threats like climate change and pollution, ash dieback presents a new serious threat for epiphytic lichens. Thirty percent of UK lichens occur on ash and the negative effect of ash dieback on lichens has been predicted to be comparable to that of climate change (Ellis et al., 2014). However, an increase in average occupancy for UK lichens since 1970 suggests communities may be starting to recover from major losses prior to this (Outhwaite, Gregory, Chandler, Collen, & Isaac, 2020).

5.4 | UKOTs fungi

The conservation status of UKOTs fungi is another major knowledge gap. More than 50% of the lichen species on St Helena are categorized as rare, and five are thought to be extinct on the island (Aptroot, 2012), but only the foliose lichen *Xanthoparmelia beccae*, endemic to St Helena is on the Global Red List (VU; Aptroot & Perez-Ortega, 2018). The Falkland Islands smut fungus, *Anthracoidea ortegae*, is VU (Denchev & Denchev, 2019).

6 | *EX SITU* COLLECTIONS

Botanic Gardens Conservation International (BGCI) maintains PlantSearch, a database of living collections and other *ex situ* collections held around the world (BGCI, 2020). Currently the database holds data on 193,310 collections (101,752 taxon names) of plant taxa held in institutions in Britain and UKOTs. PlantSearch is used to measure progress toward Target 8 of the Global Strategy for Plant Conservation by tracking which threatened species are in global botanical collections (GSPC, 2020).

Ex situ living collections maintained by botanic gardens and similar organizations play a vital role in long-term conservation of native plants. For example, only six original individuals of the Welsh endemic *Cotoneaster cambricus* remain in the wild, with threats from grazing and hybridization with invasive *Cotoneaster* spp. To protect it from extinction, the National Botanic Garden of Wales, Treborth Botanic Garden, Chester Zoo, and Fossil Plants are growing *ex situ* collections for conservation and reintroduction (NBGW, 2020b).

Many UKOTs species of conservation concern are maintained as living collections for long-term conservation, e.g., at Kew (Clubbe et al., 2010; Corcoran, Hamilton, & Clubbe, 2014), British Virgin Islands (Hamilton, 2015; Hamilton et al., 2017), Cayman Islands (Burton, 2008), and St Helena (Goodenough, 1985; Lambdon, 2012). Many territories are growing threatened species for reintroduction programmes, e.g., in Turks and Caicos Islands *Pinus caribaea* var. *bahamensis* (Sanchez et al., 2019), and on Ascension including *Anogramma ascensionis* (Baker et al., 2014). Four protected ferns are being grown in Bermuda (Copeland et al., 2016; Sarkis, 2010) including *Diplazium laffanianum*, an endemic fern Extinct in the Wild (Copeland & Malcolm, 2014). St Helena has three specialist nurseries, including the long-established Endemic Plant Nursery in Scotland, to support restoration programmes for the Peaks National Park, the Millennium Forest, and other key sites across the island (SAERI, 2020; St Helena Government, 2020).

Seed banking is a valuable, cost-effective, long-term means of safeguarding plants *ex situ*. Seed banks ensure that seed of suitable provenance is available for reintroductions and restoration of degraded landscapes. Kew's Millennium Seed Bank (MSB) is the largest *ex situ* wild species seed bank and includes seed collections from the UK from the late 1960s and UKOTs from the mid-1990s (MSB, 2020). A primary focus in the UK has been to secure at least one collection from the broadest range of native species, particularly threatened and endemic taxa. The collections comprise 7,440 wild-origin and cultivated collections representing 1,754 native and archaeophyte taxa (72% of the UK's native and archaeophyte flora), and 78% of all threatened taxa (Table 7). Collection continues to fill gaps, mainly of rare, specialized, and taxonomically complex species and those that do not reliably produce seed in the UK.

Greater emphasis is being placed on increasing intraspecific sampling depth, conserving large collections that capture genetic diversity within and between populations across species ranges (Willis et al., 2018). The UK National Tree Seed Project developed an innovative sampling strategy to capture genetic diversity at national, eco-geographical, and individual mother plant scales (Kallow & Trivedi, 2017). Seventy-five native species have been collected, with multiple-origin samples for 49, a total of >1,300 collections from c.10,900 individual trees.

These *ex situ* seed collections represent an exceptional resource for conservation and research, including the identification of useful traits and adaptations in response to environmental change and novel pests and diseases. Their value depends on the quality and quantity of seed stored and the quality and depth of information recorded (habitat, locality, sampling detail, germination, and viability data). Accessibility of seed and data are also crucial. In 2015–2019, 1,455 samples from UK collections were distributed via the MSB seed list. Germination data are available via the Seed Information Database (Royal Botanic Gardens & Kew, 2020b), and more bespoke requests for seeds, research, technical support, and training are provided by the UK Native Seed Hub (Royal Botanic Gardens & Kew, 2020c).

The National Seed Bank of Wales was established at The National Botanic Garden of Wales in 2019 to increase the genetic and taxonomic diversity of Welsh native species that have been banked, working with the Millennium Seed Bank Partnership (MSB, 2020; NBGW, 2020a).

Most UKOTs have participated in the Millennium Seed Bank Partnership (MSB, 2020), with the aim of banking their entire flora, starting with priority threatened, and economically and culturally important species. Table 8 summarizes current holdings. A total of 1,157 collections of 617 native taxa (103 endemics) are currently banked, representing c. 27% of the UKOTs flora (c. 54% of the endemics). Multiple collections from different populations are banked

TABLE 7 Overview of UK native and archaeophyte seed collections held in Kew's Millennium Seed Bank (MSB)

	Collections in MSB[a]	Taxa in the MSB[b]	Taxa in UK flora[b]	% of UK flora in MSB
Wild origin	6,341	1,700	2,429	70
Regenerated	1,099	415	2,429	17
Total	7,440	1754	2,429	72
Threatened[c], wild	1,141	360	516	70
Threatened[c], regenerated	488	168	516	33
Total	1,629	403	516	78

[a]Data for MSB collections were extracted from the MSB's Seed Bank Database (MSB, 2020), comprising angiosperm native and archaeophyte taxa collected in the UK including subspecific taxa and critical apomictic species from the *Hieracium*, *Rubus*, *Sorbus*, and *Taraxacum* groups.

[b]MSB data were cross-referenced with the UK's angiosperm native and archaeophyte flora using data from the Botanical Society of Britain and Ireland (BSBI, 2020) and the Atlas of British and Irish Hawkweeds (McCosh & Rich, 2018). Total number of UK flora taxa excludes hybrids and aggregate groups other than *Hieracium*, *Rubus*, *Sorbus*, and *Taraxacum* species.

[c]All threatened taxa for Great Britain (IUCN Red List categories EX-VU) were identified using data from the Botanical Society of Britain and Ireland (BSBI, 2020) and the Atlas of British and Irish Hawkweeds (McCosh & Rich, 2018).

TABLE 8 UKOTs *ex situ* collections held at Millennium Seed Bank. Data extracted from the MSB's Seed Bank Database (MSB, 2020)

Territory	Total native taxa	Number taxa banked at MSB	% flora banked	Number of endemic species banked at MSB	% endemic flora banked
Anguilla	329	15	5	1	50
Ascension Island	41	14	34	6	86
Bermuda	220	10	5	7	70
British Antarctic Territory	3	2	67	0	[a]
British Indian Ocean Territory	59	2	3	0	[a]
British Virgin Islands	874	103	12	3	75
Cayman Islands	606	19	3	6	21
Falkland Islands	181	146	81	14	100
Gibraltar	550	3	1	1	100
Montserrat	761	90	12	2	67
Pitcairn	106	1	1	1	5
Saint Helena	102	43	42	42	95
South Georgia	26	26	100	0	[a]
South Sandwich Islands	3	0	0	0	[a]
Tristan da Cunha	106	20	19	14	29
Turks and Caicos Islands	436	187	43	6	67

[a]No endemics recorded in these territories.

to maximize genetic diversity of these taxa and provide long-term options for conservation and restoration.

7 | CONCLUSIONS

Detailed knowledge of biodiversity is a fundamental requirement for wise management of natural resources and to harness society support for conservation. This review has highlighted many gaps in our knowledge of the plants and fungi of the UK and UKOTs. Exploration and research on the vascular plant flora of the UK have received much attention over the last 100+ years, and we can almost say that we have a complete baseline knowledge, and work on monitoring trends and changes is ongoing. In contrast, work across the UKOTs is still in the exploration phase with some territories lacking sufficiently up-to-date records of their flora to enable effective conservation measures in a changing world. There is an urgent need to secure significant resources to complete this exploratory phase so that territories can more effectively conserve and sustainable utilize their floras. For non-vascular plants, particularly algae, the knowledge base is patchier with many gaps evident. However, the biggest gaps remain in our knowledge of fungi, particularly for groups other than lichens and Basidiomycota.

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